

# UTILITY PATENT APPLICATION TRANSMITTAL

(Only for use in filing provisional applications under 37 CFR 1.53(b))

Attorney Docket No.

199153US2S

First Inventor or Application Identifier

Naohisa KAMIYAMA

Title

ULTRASOUND DIAGNOSTIC APPARATUS

## APPLICATION ELEMENTS

Chapter 600 concerning utility patent application contents

ADDRESS TO:

Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

1. Transmittal Form (e.g. PTO/SB/17)  
(Submit an original and a duplicate for fee processing)

2. ☒ Specification Total Sheets **55**

3. ☒ Drawing(s) (35 U.S.C. 113) Total Sheets **11**  
(Formals)

4. ☒ Oath or Declaration Total Pages **2**

a. ☒ Newly executed (original)

b. ☒ Copy from a prior application (37 C.F.R. §1.63(d))  
(for continuation / divisional w/ box 16 completed)

i. ☐ DELETION OF INVENTOR(S)

Signed statement attached deleting inventor(s) named in  
the prior application, see 37 C.F.R. §1.63(d)(2) and  
1.33(b).

5. ☐ CD-ROM or CD-R in duplicate, large table or Computer  
Program (Appendix)

6. ☐ Nucleotide and/or Amino Acid Sequence Submission  
(if applicable, all necessary)

a. ☐ Computer Readable Form (CRF)

b. Specification or Sequence Listing on:

i. ☐ CD-ROM or CD-R (2 copies); or

ii. ☐ Paper

c. ☐ Statements verifying identity of above copies

## ACCOMPANYING APPLICATION PARTS

7. ☒ Assignment Papers (cover sheet & document(s))

8. ☐ Application Data Sheet. See 37 CFR 1.76

9. ☐ 37 C.F.R. §3.73(b) Statement ☐ Power of Attorney  
(when there is an assignee)

10. ☐ English Translation Document (if applicable)

11. ☒ Information Disclosure  
Statement (IDS)/PTO-1449 ☒ Copies of IDS  
Citations (1)

12. ☐ Preliminary Amendment

13. ☒ White Advance Serial No. Postcard

14. ☒ Certified Copy of Priority Document(s) (1)  
(if foreign priority is claimed)

15. ☐ Applicant claims small entity status.  
See 37 CFR 1.27

16. ☒ Other: Notice of Priority, List of Related Cases

16. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application no.:

Prior application information: Examiner:

Group Art Unit:

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

17. Amend the specification by inserting before the first line the sentence:

☐ This application is a ☐ Continuation ☐ Division ☐ Continuation-in-part (CIP)  
of application Serial No. Filed on

☐ This application claims priority of provisional application Serial No. Filed

## 18. CORRESPONDENCE ADDRESS



**22850**

(703) 413-3000

FACSIMILE: (703) 413-2220

Name:	Marvin J. Spivak	Registration No.:	24,913
Signature:	<i>Chm McCloud</i>	Date:	10/27/00
Name:	C. Irvin McCloud	Registration No.:	

Registration Number 27,124

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

INVENTOR(S) Naohisa KAMIYAMA  
 SERIAL NO: New Application  
 FILING DATE: Herewith  
 FOR: ULTRASOUND DIAGNOSTIC APPARATUS

## FEE TRANSMITTAL

ASSISTANT COMMISSIONER FOR PATENTS  
 WASHINGTON, D.C. 20231

FOR	NUMBER FILED	NUMBER EXTRA	RATE	CALCULATIONS
TOTAL CLAIMS	28 - 20 =	8	× \$18 =	\$144.00
INDEPENDENT CLAIMS	12 - 3 =	9	× \$80 =	\$720.00
<input type="checkbox"/> MULTIPLE DEPENDENT CLAIMS (If applicable)			+ \$270 =	\$0.00
<input type="checkbox"/> LATE FILING OF DECLARATION			+ \$130 =	\$0.00
BASIC FEE				\$710.00
TOTAL OF ABOVE CALCULATIONS				\$1,574.00
<input type="checkbox"/> REDUCTION BY 50% FOR FILING BY SMALL ENTITY				\$0.00
<input type="checkbox"/> FILING IN NON-ENGLISH LANGUAGE			+ \$130 =	\$0.00
<input checked="" type="checkbox"/> RECORDATION OF ASSIGNMENT			+ \$40 =	\$40.00
TOTAL				\$1,614.00

- ☐ Please charge Deposit Account No. 15-0030 in the amount of \_\_\_\_\_ A duplicate copy of this sheet is enclosed.
- ☒ A check in the amount of **\$1,614.00** to cover the filing fee is enclosed.
- ☒ The Commissioner is hereby authorized to charge any additional fees which may be required for the papers being filed herewith and for which no check is enclosed herewith, or credit any overpayment to Deposit Account No. 15-0030. A duplicate copy of this sheet is enclosed.

Respectfully Submitted,

OBLON, SPIVAK, MCCLELLAND,  
 MAIER & NEUSTADT, P.C.

*Marvin J. Spivak*  
 Marvin J. Spivak  
 Registration No. 24,913  
*C. Irvin McClelland*  
 Registration Number 21,124

Date: 10/27/00



**22850**

Tel. (703) 413-3000  
 Fax. (703) 413-2220  
 (OSMMN 10/00)

002211-5366966

TITLE OF THE INVENTION

ULTRASOUND DIAGNOSTIC APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application is based upon and claims the  
benefit of priority from the prior Japanese Patent  
Application No. 11-309381, filed October 29, 1999,  
the entire contents of which are incorporated herein by  
reference.

BACKGROUND OF THE INVENTION

10 The present invention relates to an ultrasound  
diagnostic apparatus suited for a contrast echo method  
using an ultrasound contrast agent mainly composed of  
microbubbles.

09556965.102700  
15 An ultrasound image diagnostic apparatus has many  
advantages which other modalities, e.g., an X-ray  
diagnostic apparatus, X-ray computer tomography  
apparatus (CT scanner), magnetic resonance imaging  
apparatus (MRI), and nuclear medicine diagnostic  
apparatus (gamma camera, SPECT, and PET), do not have.  
20 For example, the ultrasound image diagnostic apparatus  
can generate and display images almost in real time  
concurrently with scanning. This apparatus is compact  
and inexpensive. In using the apparatus, there is no  
chance of exposure to radiation. The apparatus can  
25 easily visualize blood flow.  
(Contrast agent)

Ultrasound contrast media are now being put into

practice, and an improvement in the precision of  
vascularity examination using such a contrast agent is  
expected. A contrast agent mainly consists of  
microbubbles of several microns. Microbubbles rapidly  
5 shrink and collapse upon reception of strong ultrasound  
waves. The contrast enhance effect therefore lasts  
only for a relatively short period of time.

In actual scan operation, since fresh contrast  
agent is continuously supplied to a scan slice over a  
10 blood flow, a certain degree of contrast enhance effect  
may be maintained. In general, however, ultrasound  
waves are applied several thousand times per second.  
In organs in which the blood flow rate is low or a  
relatively thin blood vessel, a contrast enhance effect  
15 can be maintained only for a moment.  
(Intermittent Transmission Method)

That a contrast agent instantaneously collapses  
upon application of ultrasound waves is the most  
serious problem in the contrast echo method. As a  
20 technique of solving this problem, an intermittent  
transmission method is available. In this technique,  
scanning is intermittently repeated in synchronism with  
the R waves in an electrocardiogram. Fresh contrast  
agent continuously flows into a slice in the intervals  
25 between scans. This ensures a contrast enhance effect  
for every scan.

00696965-102700

(Harmonic Imaging)

00666965-102700

The utility of the above contrast echo method is augmented if it is used in combination with a harmonic imaging method. Microbubbles vibrate nonlinearly when ultrasound waves collide with them. This nonlinear vibrations produce harmonic components having frequencies of integer multiples of a fundamental frequency. Harmonic imaging is an imaging technique of extracting harmonic components from a fundamental frequency component and visualizing them. Organs hardly vibrate nonlinearly, and hence harmonic components from the organs is relatively small. Consequently, a region where a contrast agent exists is relatively emphasized.

As described above, if the intermittent transmission method is used, since fresh microbubbles flow into a slice during scan intervals, a contrast enhance effect can be maintained. On the other hand, in order to ensure a certain spatial resolution, about 100 to 200 ultrasound scanning lines are required per frame. That is, ultrasound pulses are applied at least a number of times equal to the number of ultrasound scanning lines in one scan.

In scanning, ultrasound pulses are transmitted while their directions are gradually changed. Therefore, microbubbles on a scanning line adjacent to a scanning line having undergone transmission/reception

may not collapse. In practice, however, since an ultrasound beam has a certain width, most microbubbles on the adjacent scanning line collapse in many cases.

In addition, the width of an ultrasound beam changes in accordance with depth. The contrast enhance effect therefore may change depending on depth. Specific problems will be described below with reference to FIGS. 1A and 1B.

When ultrasound pulses are generated from a plurality of arrayed transducers 51 while the generation timing is gradually shifted, a convergent sound field is formed. The depth of ultrasound focus point can be arbitrarily changed by changing the timing. Referring to FIG. 1A, when a focus point is formed on a scanning line with an arrow 52 at a relatively short distance, a region exhibiting a relatively high pressure sound, i.e., a region 53 exhibiting a relatively high degree of microbubble collapse (microbubble collapse region), is indicated by the hatching. The dotted lines represent adjacent ultrasound scanning lines 54.

As shown in FIG. 1A, a short-distance focus point is often formed by driving only transducers near the center instead of driving all the transducers 51. In this case, in the short-distance region, the ultrasound beam is narrow, and hence the microbubble collapse range 53 is also narrow. In the long-distance

09696965-102700

region, the ultrasound beam is relatively wide,  
but the ultrasound scanning line pitch is also large.  
In addition, ultrasound waves greatly attenuate because  
of the long propagation distance. As a result, the  
5 microbubble collapse range 53 becomes relatively  
narrow.

FIG. 1B shows a microbubble collapse range 55  
when a focus point is formed at a relatively long  
distance. As shown in FIG. 1B, to ensure a certain  
10 degree of sound pressure at the focus point even at  
a long distance with a long propagation distance,  
many transducers must be driven at a high voltage.  
In this case, in the short-distance region, the  
ultrasound beam becomes wide and the microbubble  
15 collapse range 55 also becomes relatively wide.  
As a consequence, microbubbles on adjacent ultrasound  
scanning lines collapse. When, therefore, ultrasound  
transmission/reception is performed afterward in this  
scanning line direction, microbubbles will have  
20 collapsed and been lost.

Another problem will be described next. Consider  
a case wherein a cardiac minor axis image is obtained  
by the contrast echo method. As shown in FIG. 2, if  
a focus point is set at a short distance in accordance  
25 with a depth 61 of a cardiac muscle front wall portion  
61, a rear wall portion 62 is hardly visualized due to  
biological damping and a curtain effect due to

microbubbles filling a cardiac cavity.

5 If a focus point is set at a long distance in accordance with the rear wall portion 62, applied ultrasound pulses collapse microbubbles on adjacent ultrasound scanning lines in the short-distance region. Therefore, no contrast enhance effect can be expected at the front wall portion 61.

09696965.102700  
10 It is known that in the sector scan method, when ultrasound waves are transmitted in a direction greatly shifted from a direction perpendicular to the probe vibration surface, a decrease in sound pressure and an increase in side lobe level occur as compared with application of ultrasound wave in the direction perpendicular to the problem vibration surface.  
15 That is, when ultrasound waves are applied to a cardiac muscle side wall portion 63, side lobes collapse microbubbles near the front wall portion 61 and rear wall portion 62.

20 It follows from the above description that it is practically impossible to transmit ultrasound waves so as to form a uniform sound field distribution on an entire scan slice. The luminance reference level is therefore not uniform within the scan slice and varies. Since scattering by tissue exhibits a relatively linear  
25 response, luminance can theoretically be made uniform by level correction for reception signals. However, a response of microbubbles exhibits strong nonlinearity,

and phenomena such as nonlinear vibrations, expansion, and collapse of microbubbles, vary in a complicated manner depending on the absolute level of applied sound pressure. Therefore, it is practically impossible to  
5 correct reception signals.

#### BRIEF SUMMARY OF THE INVENTION

It is an object of the present invention to allow an ultrasound diagnostic apparatus to exhibit a contrast enhance effect based on an ultrasound contrast  
10 agent within a slice as uniformly as possible.

An ultrasound diagnostic apparatus according to the present invention comprises an ultrasound diagnostic apparatus for obtaining an ultrasound image of a subject into which an ultrasound contrast  
15 agent mainly composed of microbubbles is injected, comprising: a probe configured to transmit/receive an ultrasound wave to/from the subject; a transmission circuit configured to drive the probe to transmit an ultrasound wave while sequentially changing a direction  
20 of an ultrasound transmission line; a reception circuit configured to generate reception line data of the number of parallel reception from ultrasound echo signals obtained by one ultrasound wave transmission; a transmission/reception control circuit configured to  
25 control the transmission and reception circuits to change the number of parallel reception during a scan sequence for generating a 1-frame ultrasound image; and

09696965-102700

an image processing unit configured to generate an ultrasound image on the basis of the reception line data.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

FIG. 1A is a view showing a microbubble collapse range when a focus point is formed at a relatively short distance in the prior art;

FIG. 1B is a view showing a microbubble collapse range when a focus point is formed at a relatively long distance;

FIG. 2 is a view for additionally explaining problems in the prior art;

FIG. 3 is a block diagram showing the arrangement

09696965.102700

of an ultrasound diagnostic apparatus according to  
the first embodiment of the present invention;

FIG. 4 is a view for explaining parallel signal  
processing used in scan operation in the first  
5 embodiment;

FIG. 5A is a view for explaining the first partial  
scan operation in the first embodiment;

FIG. 5B is a view for explaining the second  
partial scan operation in the second embodiment;

10 FIG. 6 is a view showing the details of FIG. 5A;

FIG. 7A is a view for explaining a multifocus  
method used in another partial scan operation in the  
first embodiment;

15 FIG. 7B is a view for explaining the partial scan  
operation in the first embodiment which uses the  
multifocus method in FIG. 7B;

FIG. 8 is a view showing an example in which the  
partial scan operation in the first embodiment is  
applied to a linear scan;

20 FIG. 9 is a block diagram showing the arrangement  
of an ultrasound diagnostic apparatus according to the  
second embodiment of the present invention;

FIGS. 10A, 10B, 10C, and 10D are views showing  
an example of local region segmentation in the second  
25 embodiment;

FIG. 11 is a view showing another example of local  
region segmentation;

0955355.102700

FIG. 12 is a view showing another example of local region segmentation;

FIG. 13 is a view showing a scan operation sequence for local regions in the second embodiment;

5        FIGS. 14A and 14B are views showing scan operation for local regions using a parallel signal processing method in the second embodiment;

FIG. 15 is a view showing changes in focal length with movement of a transmission beam;

10        FIG. 16 is a view showing an ultrasound wave application procedure using a multishot method in the second embodiment;

FIGS. 17A, 17B, and 17C are views showing a method of displaying local regions in the second embodiment;

15        FIG. 18 is a block diagram showing an ultrasound diagnostic apparatus according to the third embodiment of the present invention;

FIG. 19 is a view showing a scanning procedure in the third embodiment;

20        FIGS. 20A, 20B, 20C, 20D, and 20E are views showing an example of a combined image of luminance portions according to the third embodiment; and

FIGS. 21A and 21B are views showing display examples in the third embodiment.

25        DETAILED DESCRIPTION OF THE INVENTION

The preferred embodiments of the present invention will be described in detail below with reference to the

09696965-102700

views of the accompanying drawing. Consider a clinical case wherein an anomalous region is identified by diagnosing the flow of blood into the liver parenchyma or cardiac muscle by the contrast echo method.

5 (First Embodiment)

(Arrangement and Flow of Signals)

FIG. 3 shows the arrangement of an ultrasound diagnostic apparatus according to the first embodiment. An ultrasound probe 1 is connected to an apparatus  
10 body 20. The apparatus body 20 scans the inside of an object to be examined by using an ultrasound beam through the ultrasound probe 1, creates tomographic image data by processing the obtained reception signal, and displays the image. An operating panel 9 having  
15 a trackball 10A, keyboard 10B, and the like is connected to the apparatus body 20. Various operator instructions such as an instruction to set a region of interest (ROI) are input to the apparatus body 20 through the operating panel 9.

20 A plurality of electroacoustic conversion elements (transducers) are arrayed on the distal end portion of the ultrasound probe 1. One or a few adjacent transducers constitute one channel. RF voltage pulses are applied from a transmitting unit 2 of the apparatus  
25 body 20 to the transducers. The transducers convert the electrical vibrations of the RF voltage pulse into mechanical vibrations. With this operation,

09696965-102700

the transducers generate ultrasound waves. Time differences in the application timing of high-frequency voltage pulses are provided between channels. These time differences, delay times in general, are set such that ultrasound waves generated by the transducers are combined into one narrow beam, and the beam is deflected as needed. By changing the delay times, the focal length and deflection angle can be arbitrarily changed. A transmission/reception control circuit (T/R) 13 controls these delay times.

Ultrasound waves propagate through the object and are reflected by an acoustic-impedance discontinuous surface located at some point in the object. The reflected waves return as echoes to the probe 1. The echoes mechanically vibrate the transducers of the probe 1. As a consequence, weak current signals are generated. A receiving unit 3 amplifies the current signals in units of channels, converts them into voltage signals, and converts them into digital signals. In addition, the receiving unit 3 adds the signals while giving them delay times that differ between the channels. This addition is processing called digital beam forming, by which a reception signal is given a directivity. The receiving unit 3 has a plurality of digital beam forming systems. The transmission/reception control circuit (T/R) 13 simultaneously generates a plurality of reception

signals having different directivities by parallel processing and differently controlling delay times between the digital beam forming systems.

5       The transmission/reception control circuit 13 implements scan operation (to be described later) according to the present invention by controlling delay times in transmission and reception. Note that scan operation is defined as operation to acquire a plurality of reception signals required for the  
10       creation of a 1-frame image. More specifically, scan operation is operation of repeating a series of ultrasound beam transmitting/receiving operations with respect to a plurality of ultrasound scanning lines constituting a scan plane. This new scan sequence  
15       makes it possible to obtain both the effect of improving the time resolution and the effect of making the contrast enhance effect of microbubbles relatively uniform within a scan plane.

20       In addition to the transmission/reception delay control function, the transmission/reception control circuit 13 has basic control functions such as the function of setting a transmission frequency and the function of shaping the waveform of a transmission pulse. As described above, by changing the delay times  
25       in transmission/reception, the transmission direction, reception direction, focal length, and ultrasound scanning line density of ultrasound beams can be

09696965-102700

arbitrarily changed. In general, parameters such as delay time and transmission frequency differ between modes such as the B-mode and color Doppler mode.

B-mode and color mode data can be simultaneously  
5 obtained by alternately transmitting these waves.

A receiver 4 and subsequent components will be described next. The receiver 4 is comprised of a logarithmic amplifier, an envelope detection circuit, a band-pass filter for extracting harmonic components  
10 from a reception signal, and the like.

An output from the receiver 4 is converted by a B-mode DSC 5 from a fan array of ultrasound scanning lines into an orthogonal array of scanning lines corresponding to a standard video format. The  
15 resultant data is sent as a bit stream to a combination circuit 6. The combination circuit 6 combines image data and additional information such as an electrocardiographic waveform and various set values into one frame, thereby forming a frame to be finally  
20 displayed on a display 7.

A memory control circuit 14 sends array conversion information to the B-mode DSC 5 and combination circuit 6.

An image memory 8 temporarily stores the signal  
25 train after the array conversion by the B-mode DSC 5 (or the signal train before the array conversion). This information is read out by an operator after

09696965.102700

a diagnosis or the like. In this case, the information is output to the display 7 through the B-mode DSC 5 and combination circuit 6.

An ECG analyzer 12 analyzes the electrocardiograph (ECG) data of the object measured by an ECG 11, extracts, for example, R waves, and generates a trigger signal to the transmission/reception control circuit 13. The ECG analyzer 12 converts the electrocardiograph data into display data and sends it to the combination circuit 6. This electrocardiograph data and tomographic image data are combined into a single frame to be displayed together on the display 7. A clock 15 is used to control intermittent transmission intervals in a diagnosis using on ECG signal, e.g., a diagnosis of an abdominal organ. Note that the operator can control the intermittent transmission intervals and timing on the operating panel, and the control operation is reflected in the transmission/reception control circuit 13.

(Scan Operation)

The scan operation in this embodiment will be briefly described by exemplifying the parallel signal processing of simultaneously generating a plurality of reception signals having different directivities for one transmitting operation. Consider a case wherein two reception signals having different directivities are obtained for one scanning operation. FIG. 4 is

09696965-102700

09696965.102700

a view for explaining the principle of parallel signal processing. Referring to FIG. 4, "r" represents an ultrasound scanning line; and "t", the transmission direction. Ultrasound pulses are transmitted under  
5 delay control corresponding to the direction of an ultrasound scanning line t1. From the resultant echo signals, digital beam formers of two systems generate two types of reception signals that are given directivities in the directions of ultrasound  
10 scanning lines r1 and r2 under two types of delay control. A reception scanning line density twice a transmission scanning line density is realized by this parallel signal processing. Obviously, four or more reception signals with different  
15 directivities can be theoretically generated for one transmitting operation.

The scan operation in this embodiment will be described in detail next with reference to FIGS. 5A and 5B. Assume that one scan plane consists of 160  
20 ultrasound scanning lines. The angle difference between adjacent ultrasound scanning lines is represented by  $\theta$ .

Scan operation for acquiring reception signals required to generate a 1-frame image is constituted by  
25 a plurality of, two in this case, partial scan operations. More specifically, in the first partial scan operation, the first portion in the scan region is

scanned, and in the second partial scan operation, the remaining, second portion in the scan region is scanned. A partial image of the first portion obtained by the first partial scan operation and a partial image  
5 of the second portion obtained by the second partial scan operation are combined into one frame, thereby completing a 1-frame image of the entire scan plane.

In the first and second partial scan operations, the focus point is fixed to a long distance. FIG. 5A  
10 shows the first partial scan operation. FIG. 5B shows the second partial operation. As shown in FIG. 5A, ultrasound transmission/reception is repeated in predetermined cycles. A transmission beam is sequentially moved from the right end to the left  
15 end of a scan plane in each transmission/reception. The intervals at which a transmission beam is moved are set to an integer multiple equal to or more than two of the angle difference  $\theta$  between ultrasound scanning lines,  $4 \cdot \theta$  in this case.

In digital beam forming, a plurality of, four  
20 in this case, reception signals having different directivities are generated in every transmission by parallel signal processing. More specifically, four reception signals having directivities corresponding to  
25 fourth ultrasound scanning lines which are symmetrical about a transmission beam are generated.

These four reception signals are subjected

09696965.102700

5        In the short-distance region A, all the four reception  
signals are written. In the long-distance region B,  
only the two reception signal corresponding to the two  
ultrasound scanning line located in the center are  
written.

In accordance with this region exhibiting a high contrast enhance effect, in the short-distance region  
25 A, all four reception signals (luminance signals) corresponding to four ultrasound scanning lines r1, r2, r3, and r4 which are symmetrical about a transmission

5           The transmission beam is then moved to t12, and  
all four reception signals (luminance signals)  
corresponding to four ultrasound scanning lines r5, r6,  
r7, and r8 which are symmetrical about the transmission  
beam t12 are written in the B-mode DSC 5. In the  
0   long-distance region B, only the two reception  
signals corresponding to the two ultrasound scanning  
lines located in the center are written in the B-mode  
DSC 5.

When the first partial scan operation is completed  
15 upon repeating this sequence, on the memory of the  
B-mode DSC 5, the entire short-distance region A is  
filled with the luminance data, and the long-distance  
region B partially has luminance data blank portions.  
These blank portions are filled with the luminance data  
20 obtained by the second partial scan operation.

Disregarding averaging, the number of times of transmission/reception required for the first partial scan operation is  $160/4 = 40$ .

As is obvious, since only the reception signals  
25 within the microbubble collapse range 100 need be  
finally used for an image, unnecessary reception  
signals need not be generated in the first partial scan

operation, i.e., the reception signals corresponding to the two outside ultrasound scanning lines in the long-distance region B need not be generated by digital beam forming.

5           The second partial scan operation will be described next. In the first partial scan operation, data blank portions are present at two adjacent ultrasound scanning lines in the long-distance region B. Referring to FIG. 5A, for example,  
10          ultrasound scanning lines r4 and r5 correspond to blank portions. In the second partial scan operation, transmission, digital beam forming, and DSC write operation are performed to fill these blanks with data, as shown in FIG. 5B.

15          Ultrasound transmission/reception is repeated in predetermined cycles like the first partial scan operation. A transmission beam is sequentially moved from the right end to the left end of a scan plane in every transmitting/receiving operation. The intervals  
20          at which the transmission beam is moved are set to  $4 \cdot \theta$  as in the first partial scan operation. However, the transmission beam in the second partial scan operation is shifted from the transmission beam in the first  
25          partial scan operation by half the moving intervals of the transmission beam, i.e.,  $2 \cdot \theta$ . With this operation, an ultrasound beam is transmitted in the direction of the center axis of each ultrasound

09595955.102700

scanning line corresponding to a blank portion formed in the first partial scan operation. The first transmission beam in the second partial scan operation is transmitted to a direction t21 between blank scanning lines r4 and r5. The next transmission beam is transmitted in a direction t22 between blank scanning lines r8 and r9. In this manner, transmission is repeated at intervals of  $4 \cdot \theta$ .

In digital beam forming, a plurality of, two in this case, reception signals having different directivities are generated by parallel signal processing for each transmitting operation. More specifically, two reception signals having directivities corresponding to left and right ultrasound scanning lines on the two sides of a transmission beam are generated.

These two reception signals are subjected to detection and luminance conversion in the receiver 4, and only the data corresponding to the data blank portions in the long-distance region B formed in the first partial scan operation are written in the B-mode DSC 5.

As described above, in the second partial scan operation, image portions are assembled such that they do not overlap the image portions generated in the first partial scan operation in FIG. 5A, and no blank portions are formed. The number of times of

00666666-102700

transmission/reception in FIG. 5B is set to 40 (39, to be exact) as in the case shown in FIG. 5A. That is, transmission/reception is performed a total of 80 times, which is equal to the number of times of transmission/reception in 2-direction parallel signal processing. That is, the frame rate does not decrease.

The merits of this scan operation will be described below. At a long-distance focus point, the beam width increases in the short-distance region A. In this short-distance region A, microbubbles collapse in a wide range. In other words, in the short-distance region A, a contrast enhance effect owing to microbubbles can be obtained in a wide range. This makes it possible to effectively generate reception signals at once from a wide range corresponding to as many as four scanning lines for one transmitting operation by 4-direction parallel signal processing. On the other hand, in the long-distance region B, the intervals between ultrasound scanning lines become larger than those between ultrasound scanning lines in the short-distance region A, and the distance from the center of a transmission beam increases, resulting in a decrease in the intensity of ultrasound waves. If 4-direction parallel signal processing is performed in this state, sensitivity deteriorates. For this reason, in the first partial scan operation, 2-direction parallel signal processing is performed.

00666665-102700

007201-5969696

In the second partial scan operation, then, only the blank regions in the first partial scan operation are filled with data. That is, the blank regions in the first partial scan operation correspond to data on scanning line pairs in the long-distance region. At a long-distance focus point, the scanning lines in these blank regions are included in the microbubble collapse range exhibiting a high contrast enhance effect. In this manner, high contrast enhance effects can be ensured in both the long- and short-distance regions.

In this case, for the sake of simplicity, the short-distance region A and long-distance region B are separated from each other by a clear boundary. To obtain a smoother image, these regions may overlap. In this case, for example, the luminance image on the overlapping portion is averaged to make the boundary less noticeable.

This scan operation is especially effective for sector scan operation in which ultrasound scanning line intervals differ in a short-distance region and long-distance region. However, effects similar to those described above can also be obtained when this operation is applied to linear scan operation in which ultrasound scanning line intervals remain unchanged in a short-distance region and long-distance region.

In addition, this technique may be used in

combination with the intermittent transmission method of performing transmission in synchronism with an ECG signal. In this case, since the application of ultrasound waves is stopped during periods other than synchronous periods, more microbubbles flow into a slice of a region of interest and are stored without collapse. Obviously, if ultrasound waves are applied in this state, more microbubbles can be detected. In addition, if the scanning method of this embodiment is used, the contrast enhance effect can be relatively improved.

(Other Examples of Scanning Method)

A multifocus method is available as a conventional method similar to the scanning method to be described below. The multifocus method is currently implemented in many apparatuses. This method will be described first with reference to FIGS. 7A and 7B. According to the multifocus method, as shown in FIG. 7A, (a) the respective ultrasound scanning lines are scanned to perform transmission/reception at a short-distance focus point so as to generate a signal component corresponding to a short-distance region A, and (b) a signal component corresponding to a long-distance region B is generated at a long-distance focus point. These two images are then combined into a 1-frame tomographic image. Each ultrasound scanning line has two focus points (represented by the heads of

the arrows in FIG. 7A), and hence the resolution increases. However, since the number of times of transmission/reception increases twice, the frame rate decreases to half. In addition, a multifocus method using three or more focus points is also available.

In the above method, if the position of the focus point is sequentially changed from the short-distance region, microbubble echoes may be detected up to a deep portion while microbubbles collapse from the short-distance region. However, microbubbles on adjacent ultrasounds collapse.

The second example of the scanning method of this embodiment, which aims at solving the above problem, will be described below with reference to FIG. 7B.

Note that the bullets on the ultrasound scanning lines represent focus points, and the numbers on the lower portion of the drawing represent a scan sequence.

As is obvious from FIG. 7B, a characteristic feature of this scanning method is that an ultrasound scanning

line r2 is scanned first at a short-distance focus point, an ultrasound scanning line r1 immediately preceding the ultrasound scanning line r2 is then scanned at a long-distance focus point, and scanning is performed in the order of r4, r3, r6, r5, .... In this manner, while the scanning beam moves forward from one set of a plurality of, two in this case, adjacent ultrasound scanning lines to another set, the beam

00000000-102700

moves backward in the transmission direction at each set. In addition, focus points are alternately switched in the short-distance region and long-distance region in each transmission, thereby obtaining the following effects.

Assume that the ultrasound scanning lines are sequentially scanned from the ultrasound scanning line r1 as in a conventional method. In this case, when an ultrasound pulse is transmitted to the ultrasound scanning line r1, microbubbles on the ultrasound scanning line r2 are affected, e.g., collapse. However, since the ultrasound scanning line r2 is scanned first, this adverse effect can be avoided. In addition, since the ultrasound scanning line r2 is scanned at a short-distance focus point, the influence of this scanning on the next ultrasound scanning line r1 is small. That is, microbubbles on the ultrasound scanning line r1 do not collapse much. As described above, this method can minimize the collapse of microbubbles on adjacent ultrasound scanning lines due to the application of ultrasound waves.

Note that if different focus points are set on the respective ultrasound scanning lines as in this case, since different sound fields are formed, echo signals on adjacent ultrasound scanning lines may be made uneven. Smoothing by, for example, averaging on adjacent ultrasound scanning line to reduce such

09696965.102700

unevenness is effective for an improvement in image quality.

Although the scanning method of the above embodiment is a scanning method represented by a sector probe, the present invention can also be applied to a linear type scanning method. As shown in FIG. 8, in the linear type scanning method, the intervals between ultrasound scanning lines do not depend on depth. However, the profile of the sound field formed by one beam is the same as that in the above method, and the influences on microbubbles on adjacent ultrasound scanning lines in a short-distance region still remain. When the present invention is to be applied to the linear type scanning method, ultrasound scanning lines are formed to be spaced from each other by a distance  $4d$ , and the ultrasound scanning lines are shifted by a distance  $2d$  to form ultrasound scanning lines spaced part from each other by the distance  $4d$ . In this case, the time required to generate one frame becomes equal to that in the scanning method in which the transmission ultrasound scanning line density is  $2d$ .

This embodiment presents a scanning procedure by which signals derived from microbubbles can be efficiently received, and the unevenness of contrast enhance effect within a slice can be corrected when one tomographic image is to be generated by the contrast echo method performed by administering a contrast

agent. With this procedure, even if an ultrasound contrast agent exhibiting the same performance as that of a conventional contrast agent is administered, the contrast enhance effect can be relatively improved. Therefore, an improvement in blood flow diagnosis ability, especially an improvement in fine blood flow diagnosis ability, is expected.

(Second Embodiment)

The second embodiment provides a partial imaging method. The partial imaging method is a method of segmenting a scan plane into a plurality of local portions and scanning each local portion in an optimal scan operation sequence, instead of sequentially moving over scanning lines within the scan plane, thereby obtaining optimal (maximum) contrast on the entire scan plane and combining the resultant data into a one frame.

(Arrangement and Flow of Signals)

FIG. 9 is a block diagram showing an ultrasound diagnosis apparatus of this embodiment. The same reference numerals as in the first embodiment denote the same parts in the first embodiment, and a detailed description thereof will be omitted. A template memory 21 stores pieces of information about a plurality of models for segmenting a scan slice into a plurality of local regions (partial regions). One optimal pattern for a sliceal shape of a portion to be diagnosed is

read out from the template memory 21 in accordance with an instruction input by the operator on an operating panel 9. This template is sent to a memory control circuit 14 first, and then displayed on a display 7 in a form in which the template is superimposed on an ultrasound diagnosis image. A signal processing unit 22 performs numeric operation such as averaging echo signals from a local region or obtaining a representative value.

A graphic unit 23 performs graphic signal processing, e.g., synthesizing an image on the basis of data sent from the signal processing unit 22 and coloring a simplified graphic pattern. The image data created by this processing is output to the display 7 through a combination circuit 6. This data is also transferred to an external computer, printer, or the like through a network board 24.

(Region Segmentation in Partial Imaging Method)

This partial imaging method is roughly constituted by three steps, i.e., (a) the step of setting a diagnosis region of interest and a local region of interest, (b) the scanning step, and (c) the display step.

(a) Setting Diagnosis Region of Interest and Local Region of Interest

First of all, it is important to set a specific local portion toward which the diagnostic apparatus is

007201-5966660

to perform optimal scanning. The settings vary depending on an organ to be diagnosed and its slice. For example, the cardiac muscle in a cardiac minor axis image has an almost circular shape. A circular  
5 template 50 representing a local region like the one shown in FIG. 10A is selected in advance. The size of the template 50 is then adjusted by using the zoom function of the operating panel 9 or the like to almost overlap the outer ring of the template 50 on the minor  
10 axis image, as shown in FIG. 10B. If the size of a template is fixed in accordance with a routine, the template need not be displayed in some case.

As shown in FIG. 10C, the operator then designates desired local regions with points or regions.

15 Obviously, a plurality of regions can be designated. In this case, regions can be set at uneven intervals along the cardiac muscle. As shown in FIG. 10D, the operator designates representative points of those set above. With this operation, the apparatus  
20 performs automatic segmentation. In this example, diametrically located four points are designated to obtain a segmented region like the one shown in FIG. 10B. Obviously, the size of a template, the number of local regions segmented, and the like  
25 can be changed.

In the above case, the cardiac minor axis image is exemplified. However, a template suited for the shape

00695965-102700

or the like of another slice, such as a 2-cavity cross section or major axis image, may be selectively used. In addition, the setting method shown in FIGS. 10C and 10D can also be used. In diagnosing the liver, since the liver is included in an overall slice, relatively simple local region segmentation like the one shown in FIG. 11 can be performed.

(b) Scan Operation

The set local regions are sequentially scanned.

In general, this scanning is started when the operator presses a start button on the operating panel 9.

In the case shown in FIG. 12, for example, when a local region A is to be irradiated, a focus point is set at the central portion of the region A.

A transmission/reception control circuit 13 changes the ultrasound transmission conditions in accordance with the position of each local position (transmission focus point) so as to almost equalize the degrees of dynamic influences on the respective local regions, i.e., sound pressures on the respective local regions and the degrees of collapse of microbubbles in the respective local regions. Typical transmission conditions that can be adjusted include the driving voltage for each transducer, the aperture width (the number of transducers to be simultaneously driven), the driving frequency, and the scanning line density.

In this case, the respective parameters are

00666665-102700

changed to almost equalize the degrees of collapse of  
microbubbles in consideration of biological damping  
(mainly determined by the transmission distance of  
ultrasound waves) and the irradiation angle with  
5 respect to each transducer. When the parameters  
associated with the driving voltage for each transducer  
and the number of transducers to be simultaneously  
driven are changed, the degrees of collapse of  
microbubbles can be made almost uniform by almost  
10 equalizing the sound pressures at the positions of the  
respective focus points. More specifically, when the  
driving voltage for each transducer is to be changed,  
the driving voltage is lowered if the focus point is  
located near, and vice versa. When the number of  
15 transducers to be driven is to be changed, the number  
of transducers to be driven is decreased if the focus  
point is located near, and vice versa. When the  
frequency is to be changed, the frequency is increased  
if the focus point is located near, and vice versa.  
20 Note that only one of the above parameters may be  
changed or a plurality of parameters may be  
simultaneously changed.

Strictly speaking, the value of damping varies  
among objects to be examined. However, a rough value  
25 can be presented to the operator on the basis of data  
obtained in advance by measurement. With reference to  
a region E exhibiting the maximum damping, relative

00201-5566666

transmission sound pressures for the respective regions are set such that -1.5 dB is set for regions D and F; -2 dB, for regions C and G, -4.5 dB, for shallow regions B and H, and -6 dB, for a shallowest region A.

5           If an effective echo signal is to be obtained by irradiating the local region E with ultrasound waves, the region A on the same ultrasound scanning lines is affected by the collapse of microbubbles. It is therefore useless to scan the region A immediately  
10           after the region E. This problem can be effectively solved by using an intermittent transmission method.

          As shown in FIG. 13, for a circulatory organ region, transmission is performed once for every heartbeat or for a few heartbeats by using triggers  
15           synchronous with an electrocardiogram. In the interval between triggers, no transmission is performed, and hence new microbubbles flow into a region of interest upon collapse of microbubbles. This makes it possible to acquire a sufficient contrast enhance effect again.

20           In the case shown in FIG. 13, at the same trigger timing, echo signals are generated from the pairs of local regions B and H, C and G, and D and F at the same heartbeat timing by using the parallel signal processing method. This is because each pair of  
25           regions are located at the same depth and same focal length, and do not affect each other, i.e., do not collapse microbubbles each other, since they are spaced

00201-596966

apart from each other. In addition, in the case shown in FIG. 13, scanning from the region A to the region H is repeated a plurality of number of times.

FIGS. 14A and 14B show another operation procedure. Assume that scanning is started from the right end of the screen. In this case, at the first trigger, as shown in FIG. 14A, the local regions A, B and C are simultaneously scanned by using 3-direction parallel signal processing. In each region, however, the focal length and output sound pressure can be changed, and the changed values are set as optimal values in each region. At the second trigger, as shown in FIG. 14B, similar scanning is performed for regions on which the ultrasound scanning lines at the first trigger overlap. In this method, the segmentation forms of local regions are not uniform unlike those in FIG. 11. A merit of the method is that microbubble echoes can be obtained relatively effectively with a smaller number of times of transmission/reception.

FIG. 15 shows an advanced method. At the first trigger, the focal length changes for each ultrasound scanning line (an illustration of ultrasound scanning lines is omitted), as indicated by "A" in FIG. 15. The output sound pressure is also controlled in accordance with a change in focal length such that output pressures on other ultrasound scanning line in this focus point portion are made uniform. At the

09696965-102700

second trigger, the focal length changes for each  
ultrasound scanning line as indicated by "B" in  
FIG. 15. As a result, at the second trigger, good  
echoes can be received from the entire circumferential  
5 portion of the cardiac muscle, and echoes can be  
acquired under a uniform sound pressure intensity along  
the circumferential portion of the cardiac muscle.

The following technique can also be used to  
extract clearer microbubble echoes. According to this  
10 technique, as shown in FIG. 16, immediately after  
an echo signal is obtained by performing a scan T1 for  
a given region, a similar scan T2 is performed for the  
same region at the above trigger timing. If the scan  
T2 is performed at this timing, microbubbles collapse  
15 by the immediately preceding scan T1, and only an echo  
signal representing a tissue remains in the echoes  
obtained by the immediately succeeding scan T2. If the  
receiver calculates the difference between the echo  
signals obtained by these two scans, only the signal  
20 derived from the collapsed microbubbles is extracted as  
a difference signal. As a consequence, the echoes  
derived from the contrast agent which are free from  
the influences of luminance of the living tissue can  
be visualized (this method will be referred to as  
25 a subtraction method hereinafter).

(c) Display

According to the data acquisition method of the

002201-596999

present invention described above, since data (signal intensity) presenting a contrast enhance effect on the entire region of interest can be obtained by executing at least two scan procedures, the technique of combining the data and displaying the resultant image is used. In the case shown in FIG. 12 or 14, since the boundaries between the respective local regions are clear, a simple image (simple signal intensity distribution) is reconstructed by the combination circuit 6 using only data from a corresponding region, and the image is displayed on the display 7.

This image combining and displaying method can be applied as follows. In diagnosing a myocardial blood flow, attention is often paid to find an ischemic region of the cardiac muscle. In this case, the operator need only know fine blood flow perfusion due to a contrast agent without paying any attention to the fine form of speckle pattern of the cardiac muscle (as in the case of a scintigram in nuclear medicine). To meet such needs in diagnosis, for example, a display method of calculating the average contrast degree of each local region and displaying the calculated value as the representative value of each local region is used. Painting each region by using color information based on a color bar or the like makes the displayed information easier to discern (FIG. 17A). Alternatively, simplified display may be performed as

shown in FIG. 17B. Furthermore, as shown in FIG. 17C, blood flow rates may be numerically expressed and displayed. Although the luminances and numerical values in display represent relative information, such a display method allows the operator to quickly detect an ischemic region of the cardiac muscle if it exists. These images may be displayed side by side as well as being overlaid on an original diagnostic image. More simplified display images can be added to a patient's chart or electronic patient's chart through a means such as a network as well as being output from a printer.

(Third Embodiment)

FIG. 18 shows the arrangement of the third embodiment. A transmission/reception control circuit 13 controls the timing of pulses from a transmitting unit. This embodiment performs intermittent transmission using a timing signal from an ECG analyzer 12 or clock 15 in accordance with a mode switching instruction sent from an operating panel 9. Intermittent transmission is transmission in which frame generation intervals are sufficiently larger than those in normal continuous transmission (20 to 100 frames/sec). For example, time intervals corresponding to four or five heartbeats are input.

The transmission/reception control circuit 13 instructs a transmitting unit 2 to perform transmission

00000000.102700

FIG. 19 shows a conceptual rendering of this

continuously transmitted/received at predetermined time intervals (sufficiently longer than the frame rate).

10        and the images are displayed on the display. Prior to  
a description of an image processing method, diagnostic  
images expected from the transmission method in FIG. 19  
will be described.

<Problems to Be Solved>

15           If the contrast agent concentration is relatively  
low or a contrast agent is made of microbubbles that  
easily collapse, most microbubbles on a slice collapse  
by a transmission pulse in the first frame. In the  
second and subsequent frames, therefore, diagnostic  
20   images are formed without any microbubbles, i.e., made  
of only tissue echoes.

25      developed contrast agent containing microbubbles that  
are relatively resistant to ultrasounds is used, the  
following phenomenon occurs.

As in FIG. 20A, in transmission of the first frame (A), a contrast enhance effect is seen at a relatively short-distant portion. However, the collapsing effect of high-concentration microbubbles at the short-distance portion increases, and hence ultrasound pulses can hardly propagate to a deeper portion. As a consequence, no image is seen at a portion deeper than the short-distance portion, and the portion becomes dark. In some case, such a portion becomes darker after administration of the contrast agent than before (called shadowing). As shown in FIG. 20B, in the second frame (B), since the microbubbles at the short-distance portion have collapsed, the contrast enhance effect decreases. However, since damping of sound waves due to microbubbles is reduced, a relatively deep portion is irradiated with a relatively high sound pressure. The contrast enhance effect at this portion increases. Subsequently, a similar phenomenon is transferred to deeper portions. When microbubbles collapse in all regions as shown in FIG. 20C, the displayed image is formed by tissue echoes (FIGS. 20D and 20E).

If this phenomenon is seen with a moving picture, the movement of the luminance based on contrast from a shallow portion to a deep portion like a curtain that drops is recognized. This phenomenon will be referred to as a "curtain phenomenon" hereinafter.

Obviously, when the above phenomenon occurs, the operator cannot examine a contrast enhance effect on an entire slice by only seeing one of a plurality of images. All the images must be joined to each other.

5 <Arithmetic Image Processing>

The image processing unit 31 described above performs optimal image combining processing when the above curtain phenomenon occurs. More specifically, images obtained at one trigger timing are stored in the image memory 8. The luminance signals of these images at the same coordinates in the respective frames are compared with each other to detect maximum values. Arithmetic processing for determining a luminance  $I(x, y)$  at coordinates  $(x, y)$  is given by

15 
$$I(x, y) = \text{MAX}(I_i(x, y)), \quad I = 1 \cdots N$$

where  $I_i(x, y)$  is the luminance at the coordinates  $(x, y)$  in the  $i$ th frame, and  $N$  is the number of images to be compared with each other.

As a result of this processing, images like those shown in FIGS. 20A, 20B, 20C, 20D, and 20E having high-luminance contrast portions joined together are combined, and the combined image is displayed on the display. As is obvious from the result, since this image displays the luminance corresponding to the highest contrast among all the regions, the operator can examine the overall contrast degree with this one diagnostic image.

Note that this technique is similar to an MIP  
(Maximum Intensity Projection) method used to  
project three-dimensional space information on a  
two-dimensional plane. However, the general MIP method  
5 is used for spatial points, whereas the technique of  
the present invention is used for temporal points.

Note that the above arithmetic processing is  
relatively simple, and a combined image is preferably  
displayed almost in real time immediately after  
10 transmission at the trigger timing.

As described above, this embodiment cannot exhibit  
a sufficient effect when no curtain phenomenon occurs,  
but has no adverse effect. Therefore, this technique  
is not used in any specified condition.

15 <Examples of Display>

FIGS. 21A and 21B show examples of a display form.  
FIG. 21A shows a method based on two-window display.  
While intermittent transmission is observed in real  
time on one window, the above combined image is  
20 sequentially displayed on the other window. Referring  
to FIG. 21B, images obtained at one trigger timing are  
displayed side by side, and a combined image is  
simultaneously displayed. Note that all image need not  
have the same size. In general, since a combined image  
25 is most important for diagnosis, the image is  
preferably displayed in a relatively large size, as  
shown in FIG. 20B.

00000000-102700

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments  
5 shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

09666665-102700

WHAT IS CLAIMED IS:

1. An ultrasound diagnostic apparatus for obtaining an ultrasound image of a subject into which an ultrasound contrast agent mainly composed of  
5 microbubbles is injected, comprising:

a probe configured to transmit/receive an ultrasound wave to/from the subject;

a transmission circuit configured to drive said probe to transmit an ultrasound wave while sequentially  
10 changing a direction of an ultrasound transmission line;

a reception circuit configured to generate reception line data of the number of parallel reception from ultrasound echo signals obtained by one ultrasound  
15 wave transmission;

a transmission/reception control circuit configured to control said transmission and reception circuits to change the number of parallel reception during a scan sequence for generating a 1-frame  
20 ultrasound image; and

an image processing unit configured to generate an ultrasound image on the basis of the reception line data.

2. An apparatus according to claim 1, wherein  
25 when generating one ultrasound image, said an image processing unit uses N adjacent reception line data generated from ultrasound echo signals obtained

00666065-102700

by one ultrasound transmission, centering around  
a transmission direction, in a short-distance region,  
and uses  $n$  ( $n < N$ ) adjacent reception line data  
generated from ultrasound echo signals obtained by  
one ultrasound transmission, centering around  
a transmission direction, in a long-distance region.

3. An apparatus according to claim 1, wherein  
said transmission/reception control circuit  
changes the number of parallel reception in a first  
partial region and a second partial region, and  
said transmission circuit sets an ultrasound focus  
point in a long-distance region when transmitting  
an ultrasound wave to the first partial region and when  
transmitting an ultrasound wave to the second partial  
region.

4. An apparatus according to claim 1, wherein  
said an image processing unit generates an ultrasound  
image on the basis of a harmonic component obtained by  
removing a fundamental wave component from the  
ultrasound echo signal.

5. An apparatus according to claim 1, wherein  
said transmission/reception control circuit changes  
the number of parallel transmission/reception to not  
less than three different numbers within one frame.

6. An ultrasound diagnostic apparatus for  
obtaining an ultrasound image of a subject into which  
an ultrasound contrast agent mainly composed of

microbubbles is injected, comprising:

a probe configured to transmit/receive an ultrasound wave to/from the subject;

5 a transmission circuit configured to drive said probe to transmit an ultrasound wave while sequentially changing a direction of an ultrasound transmission line;

10 a reception circuit configured to generate reception line data of the number of times of parallel reception from ultrasound echo signals obtained by one ultrasound wave transmission; and

15 an image processing unit configured to generate one ultrasound image by using reception line data in a short-distance region and long-distance region, generated on the basis of transmission of a first ultrasound signal, reception line data in the short-distance region, generated on the basis of the first ultrasound transmission, and reception line data in the long-distance region, generated on the basis of second ultrasound transmission.

20 7. An ultrasound diagnostic apparatus for obtaining an ultrasound image of a subject into which an ultrasound contrast agent mainly composed of microbubbles is injected, comprising:

25 a probe configured to transmit/receive an ultrasound wave to/from the subject;

a transmission circuit configured to drive said

006696965.102700

probe to transmit an ultrasound wave while sequentially changing a direction of an ultrasound transmission line and drive said probe such that the ultrasound transmission lines are formed into a plurality of sets each constituted by a plurality of adjacent transmission lines, scanning is performed with respect to the plurality of sets in a forward direction, and scanning is performed in a reverse direction in each of the sets;

a reception circuit configured to generate reception line data from an ultrasound echo signal obtained by the ultrasound transmission; and

an image processing unit configured to generate an ultrasound image on the basis of the reception line data.

8. An apparatus according to claim 7, wherein said transmission circuit sequentially switches a focus point position of an ultrasound wave to be transmitted in a scan sequence for obtaining a 1-frame ultrasound image at a long distance and short distance.

9. An ultrasound diagnostic apparatus for obtaining an ultrasound image of a subject into which an ultrasound contrast agent mainly composed of microbubbles is injected, comprising:

a probe configured to transmit/receive an ultrasound wave to/from the subject;

a transmission circuit configured to drive said

0066965-102700

probe to transmit an ultrasound wave while sequentially changing a direction of an ultrasound transmission line;

5       a reception circuit configured to generate reception line data from ultrasound echo signals obtained by transmission of the ultrasound wave; and

      a transmission/reception control circuit configured to control said transmission and reception circuits to scan a plurality of local regions within  
10       a scan slice in different transmission conditions.

      10. An apparatus according to claim 9, wherein said transmission/reception control circuit performs transmission in different transmission conditions in the respective local regions so as to correct  
15       a difference in collapse degree of the bubbles due to an influence of a tissue distribution in the object.

      11. An apparatus according to claim 9, wherein said transmission control circuit changes at least one of a driving voltage for a transducer, a size of  
20       a focus point, an opening area, the number of elements driven by an ultrasound transducer, and an ultrasound transmission frequency.

      12. An apparatus according to claim 9, wherein said transmission/reception control circuit  
25       respectively sets transmission conditions for the plurality of local regions so as to make transmission sound pressures constant with respect to the plurality

00000000-102700

of local regions.

13. An apparatus according to claim 9, further comprising a storage unit storing a plurality of patterns of templates indicating a shape in which the slice is segmented into local regions and transmission conditions in the respective local regions.

14. An apparatus according to claim 9, further comprising an input device configured to segment the slice into a plurality of local regions.

15. An apparatus according to claim 9, wherein said transmission/reception control circuit comprises an input device for manually designating at least one representative point within the slice, and means for obtaining a segmentation shape of the slice in accordance with the designated representative point.

16. An apparatus according to claim 9, wherein said an image processing unit generates a mosaic image on the basis of a reception signal intensity obtained for each of the local regions.

17. An apparatus according to claim 16, wherein the mosaic image is painted in colors corresponding to the reception signal intensities for the respective local regions.

18. An apparatus according to claim 16, wherein numerical values or characters corresponding to the reception signal intensities in the respective local

09696965.102700



5

10

15

20

an image generating unit configured to generate an image by combining portions of the reception line data on the single scanning line.

25

performing first ultrasound transmission to sequentially transmit ultrasound waves while

sequentially changing a direction of an ultrasound transmission line;

performing second ultrasound transmission to transmit an ultrasound wave to a line between  
5 ultrasound transmission lines in the first ultrasound transmission;

performing first reception to generate reception line data of a plurality of reception scanning lines from ultrasound echo signals obtained by performing  
10 the first ultrasound transmission once;

performing second reception to generate reception line data of reception scanning lines different in number from that in the step of performing the first reception from ultrasound echo signals obtained by  
15 performing the second ultrasound transmission once; and

generating one ultrasound image by combining the reception line data obtained in the step of performing the first and second receptions.

24. A scanning method for an ultrasound diagnostic  
20 apparatus for obtaining an ultrasound image of a subject into which an ultrasound contrast medium mainly composed of microbubbles is injected, comprising the steps of:

performing first ultrasound transmission to  
25 sequentially transmit ultrasound waves while sequentially changing a direction of an ultrasound transmission line;

09696965.102700

performing second ultrasound transmission to transmit an ultrasound wave to a line between ultrasound transmission lines in the first ultrasound transmission;

5           generating first reception line data on the basis of ultrasound echo signals of a short-distance portion and long-distance portion obtained by the first ultrasound transmission, and generating second reception line data on the basis of the ultrasound echo  
10       signal of the short-distance portion obtained by the first ultrasound transmission and the ultrasound echo signal of the long-distance portion obtained by the second ultrasound transmission; and

          generating a 1-frame ultrasound image on the basis  
15       of the reception line data.

25. A scanning method for an ultrasound diagnostic apparatus for obtaining an ultrasound image of a subject into which an ultrasound contrast medium mainly composed of microbubbles is injected, comprising the  
20       steps of:

          transmitting ultrasound waves such that the ultrasound transmission lines are formed into a plurality of sets each constituted by a plurality of adjacent transmission lines, scanning is performed  
25       with respect to the plurality of sets in a forward direction, and scanning is performed in a reverse direction in each of the sets;

00696965-102700

generating reception line data from an ultrasound echo signal obtained by the ultrasound transmission; and

5 generating an ultrasound image on the basis of the reception line data.

26. A scanning method for an ultrasound diagnostic apparatus for obtaining an ultrasound image of a subject into which an ultrasound contrast medium mainly composed of microbubbles is injected, comprising the  
10 steps of:

transmitting/receiving an ultrasound wave in different transmission conditions in local regions so as to correct a difference in collapse degree of the bubbles due to an influence of a tissue distribution in  
15 the object; and

generating an ultrasound image on the basis of an ultrasound echo obtained by the ultrasound transmission.

27. A scanning method for an ultrasound diagnostic  
20 apparatus for obtaining an ultrasound image of a subject into which an ultrasound contrast medium mainly composed of microbubbles is injected, comprising the steps of:

25 transmitting/receiving an ultrasound wave to form a period during which a contrast medium flows into the object and a period during which microbubbles are collapsed by an ultrasound wave, and performing the

09606065-102700

ultrasound transmission/reception corresponding to a plurality of frames in the microbubble collapse period; and

5 generating images of the plurality of frames on the basis of ultrasound echo signals obtained by the transmission/reception, and generating a combined image by combining the respective images.

28. A scanning method for an ultrasound diagnostic apparatus for obtaining an ultrasound image of a  
10 subject into which an ultrasound contrast medium mainly composed of microbubbles is injected, comprising the steps of:

transmitting/receiving an ultrasound wave to form a period during which a contrast medium flows into the  
15 object and a period during which microbubbles are collapsed by an ultrasound wave and performing ultrasound transmission/reception on a single scanning line a plurality of number of times;

generating reception line data from an ultrasound  
20 echo signal obtained by the transmission/reception; and

generating an image by combining portions of the reception line data on the single scanning line.

00666065-102700

ABSTRACT OF THE DISCLOSURE

An ultrasound diagnostic apparatus for obtaining an ultrasound image of a subject into which an ultrasound contrast agent mainly composed of microbubbles is injected, comprising a probe configured to transmit/receive an ultrasound wave to/from the subject, a transmission circuit configured to drive the probe to transmit an ultrasound wave while sequentially changing a direction of an ultrasound transmission line, a reception circuit configured to generate reception line data of the number of parallel reception from ultrasound echo signals obtained by one ultrasound wave transmission, a transmission/reception control circuit configured to control the transmission and reception circuits to change the number of parallel reception during a scan sequence for generating a 1-frame ultrasound image, and an image processing unit configured to generate an ultrasound image on the basis of the reception line data.

09505055-102700

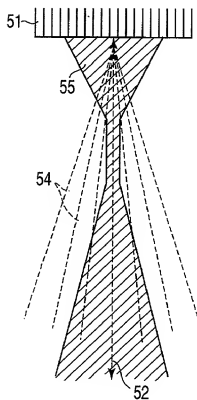


FIG. 1A PRIOR ART

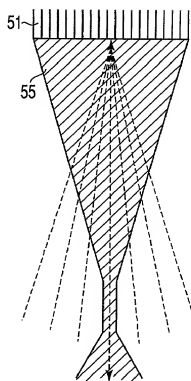


FIG. 1B PRIOR ART

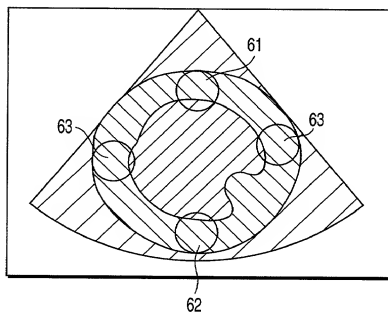


FIG. 2 PRIOR ART

0966965-102700

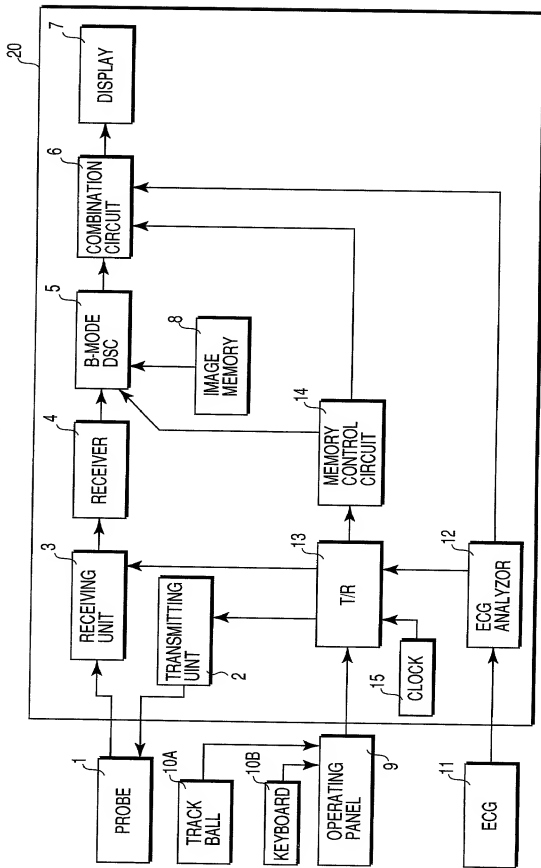


FIG. 3

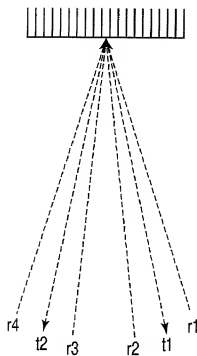


FIG. 4

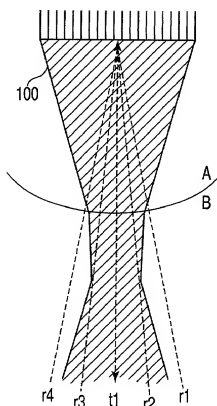


FIG. 6

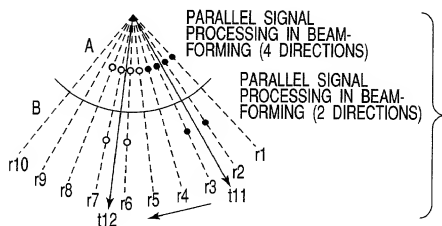


FIG. 5A

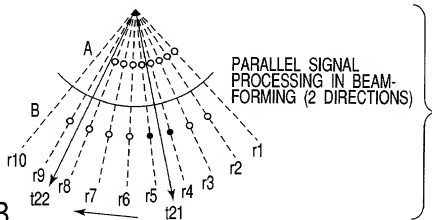


FIG. 5B

00596965-102700

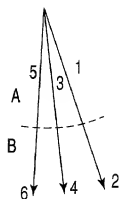


FIG. 7A

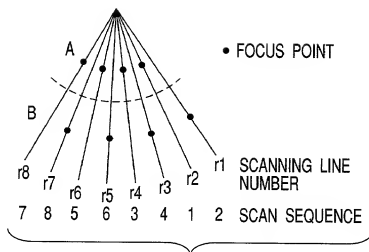


FIG. 7B

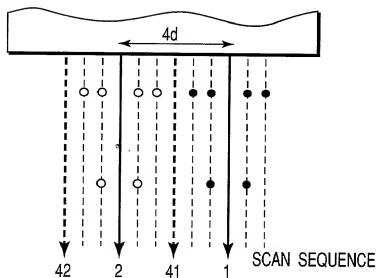


FIG. 8

03696965.102700

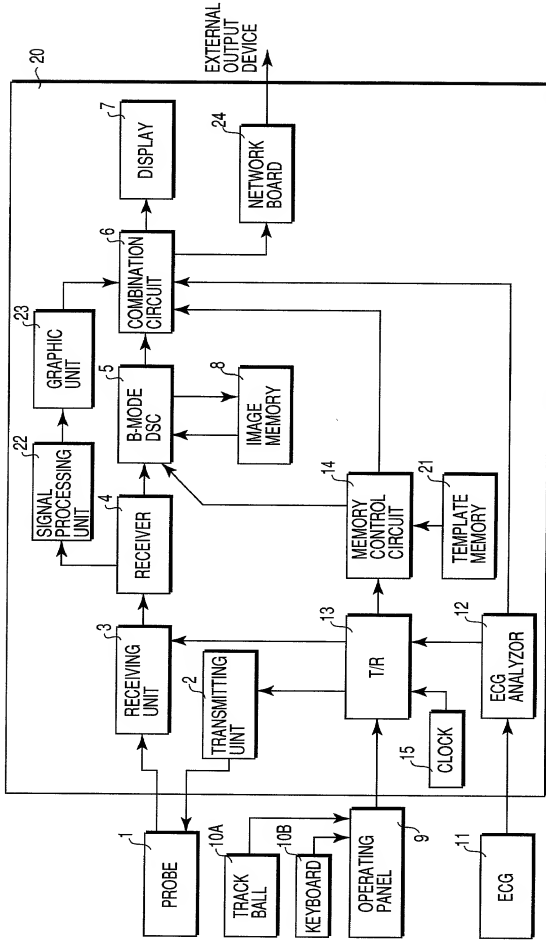


FIG. 9

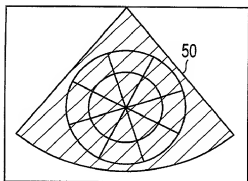


FIG. 10A

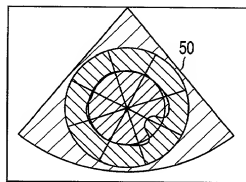


FIG. 10B

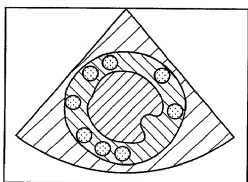


FIG. 10C

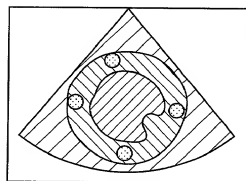


FIG. 10D

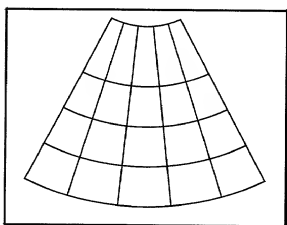


FIG. 11

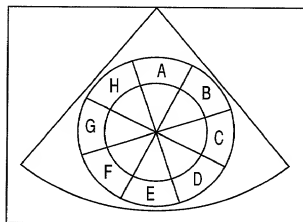


FIG. 12

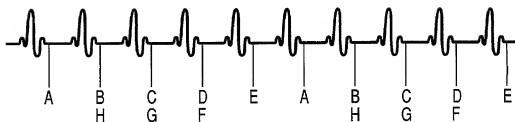
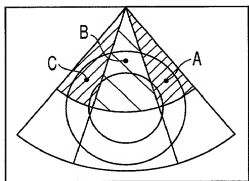
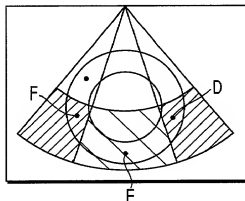


FIG. 13



FIRST TRIGGER

FIG. 14A



SECOND TRIGGER

FIG. 14B

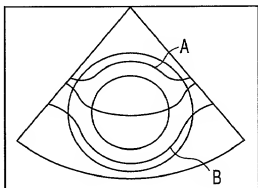


FIG. 15

00696965-10700



FIG. 16

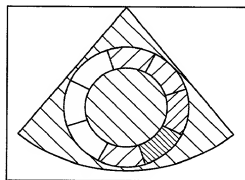


FIG. 17A

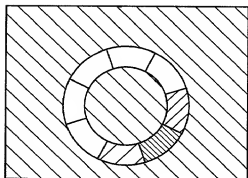


FIG. 17B

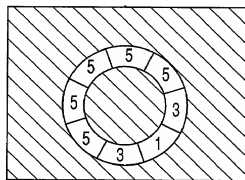


FIG. 17C

09696965-102700

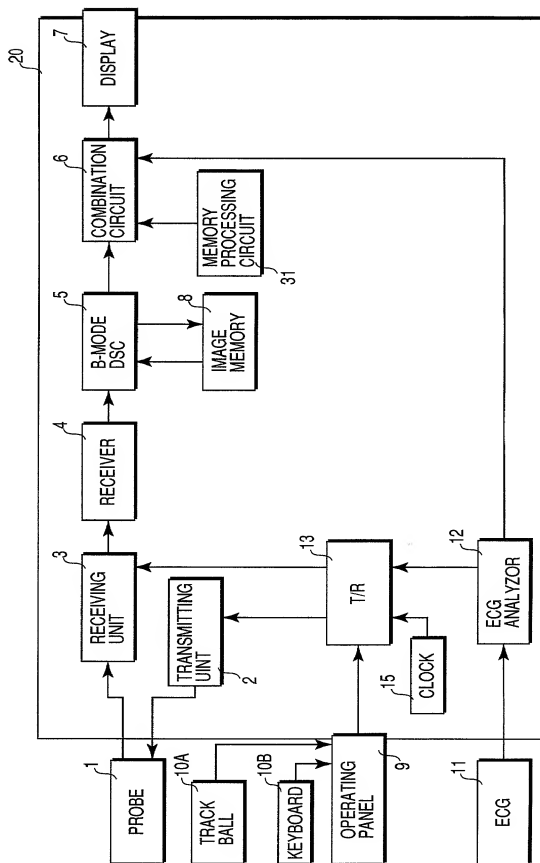


FIG. 18

CONTINUOUS  
 SCANNING PERIOD  
 (5 SCANS ex.)

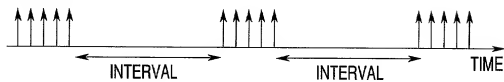


FIG. 19

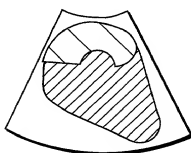


FIG. 20A

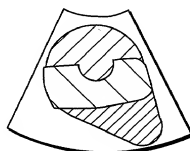


FIG. 20B

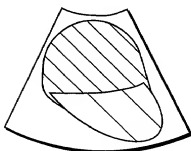


FIG. 20C

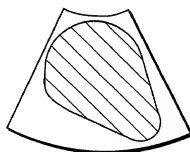


FIG. 20D

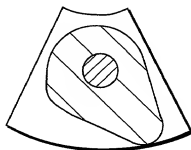
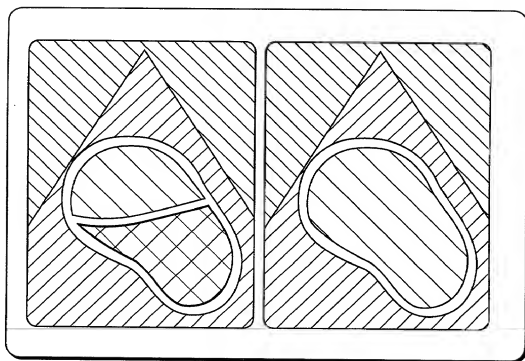


FIG. 20E

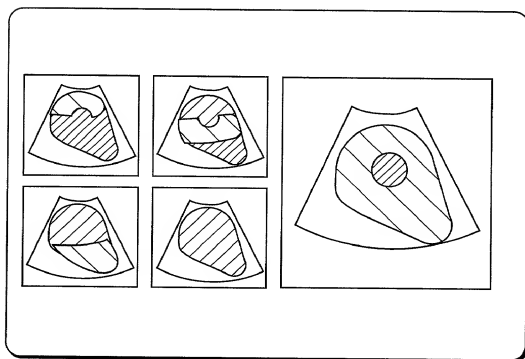
00696965.102700



REAL TIME IMAGE

COMBINED IMAGE

FIG. 21A



TRIGGER IMAGES

COMBINED IMAGE

FIG. 21B

00666955-102700

## DECLARATION FOR PATENT APPLICATION

00S0879

As a below named inventor, I declare:  
that I verily believe myself to be the original, first and sole (if only one individual inventor is listed below) or an original first and joint inventor (if more than one individual inventor is listed below) of the invention in

## ULTRASOUND DIAGNOSTIC APPARATUS

the specification of which is attached hereto unless the following box is checked.

☐ was filed on \_\_\_\_\_ as United States Application  
or PCT International Application No. \_\_\_\_\_, and  
was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information of which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365 (b) of any foreign application(s) for patent or inventor's certificate, or 35 U.S.C. 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed:

Country	Category	Application No.	Filing Date	Priority Claim
Japan	Patent	11-309381	October 29, 1999	Yes

And I hereby appoint Norman F. Oblon (Reg. No. 24,618), Marvin J. Spivak (Reg. No. 24,913), C. Irvin McClelland (Reg. No. 21,124), Gregory J. Maier (Reg. No. 25,599), Arthur I. Neustadt (Reg. No. 24,854), Richard D. Kelly (Reg. No. 27,757), James D. Hamilton (Reg. No. 28,421), Eckhard H. Kuesters (Reg. No. 28,870), Robert T. Pous (Reg. No. 29,090), Charles L. Gholz (Reg. No. 26,395), Vincent J. Sunderdick (Reg. No. 29,004), William E. Beaumont (Reg. No. 30,996), Robert F. Gnuse (Reg. No. 27,295), Jean-paul Lavalleye (Reg. No. 31,451), Stephen G. Baxter (Reg. No. 32,884), Robert W. Hahl (Reg. No. 33,893), Richard L. Treanor (Reg. No. 36,379), Steven P. Wehrouch (Reg. No. 32,829), John T. Gookasian (Reg. No. 26,142), Richard L. Chinn (Reg. No. 34,305), Steven E. Lipman (Reg. No. 30,011), Carl E. Schlier (Reg. No. 34,426), James J. Kulbaski (Reg. No. 34,648), Richard A. Nelfeld (Reg. No. 35,299), J. Derek Meaon (Reg. No. 35,270), Surinder Sachar (Reg. No. 34,423), Christina M. Gadiano (Reg. No. 37,628), Jeffrey B. McIntyre (Reg. No. 36,867), Paul E. Rauch (Reg. No. 38,591), William T. Enos (Reg. No. 33,128) and Michael E. McCabe, Jr., (Reg. No. 37,182) each of whose address is Fourth Floor, 1755 Jefferson Davis Highway, Arlington, Virginia 22202, or any one of them, my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent & Trademark Office connected therewith, and request that correspondence be directed to Oblon, Spivak, McClelland, Mailer & Neustadt, P.C., Fourth Floor, 1755 Jefferson Davis Highway, Arlington, Virginia 22202.

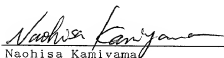
I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

09696965-102700

## DECLARATION FOR PATENT APPLICATION

00S0879

I declare further that my post office address is at c/o  
Intellectual Property Division, KABUSHIKI KAISHA TOSHIBA, 1-1 Shibaura  
1-chome, Minato-ku, Tokyo 105-8001, Japan; and  
that my citizenship and residence are as stated below next to my name:

Inventor: (Signature)DateResidenceDate: OCT. 18. 2000  
Naohisa KamiyamaCitizen of: JapanOtawara-shi, JapanDate:Citizen of: JapanDate:Citizen of: JapanDate:Citizen of: JapanDate:Citizen of: JapanDate:Citizen of: JapanDate:Citizen of: JapanDate:Citizen of: Japan

09696965.102709